Climate Simulation and Climate Change in Southern California

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What are Regional Climate Models?

Regional climate models are intricate pieces of software that rely on the the heavy number-crunching capacity of supercomputers to solve the basic equations governing the behavior of the atmosphere and ocean on a limited-area grid.

The relatively small domain allows limited computational resources to be invested in high resolution (order few km in the horizontal).

The high resolution facilitates the study of climate and ecosystems at scales nearing the landscape scale, where environmental effects are of the greatest relevance to humans and ecosystems.

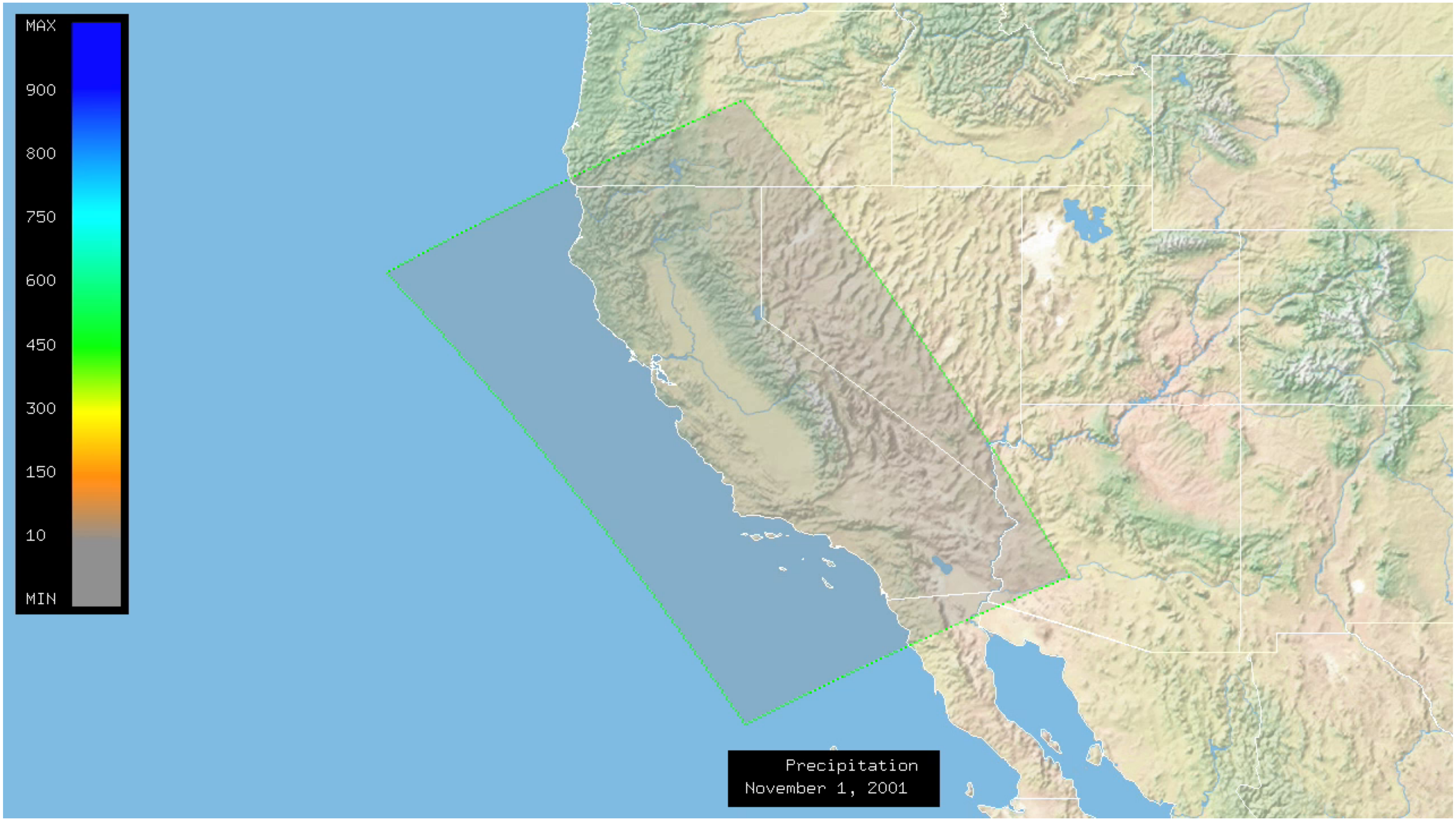
The regional climate model we use has three interacting components: WRF (atmosphere), NOAH (land surface), and ROMS (ocean).

A regional climate simulation responds to conditions imposed at its outer boundaries…

This information can come from two sources:

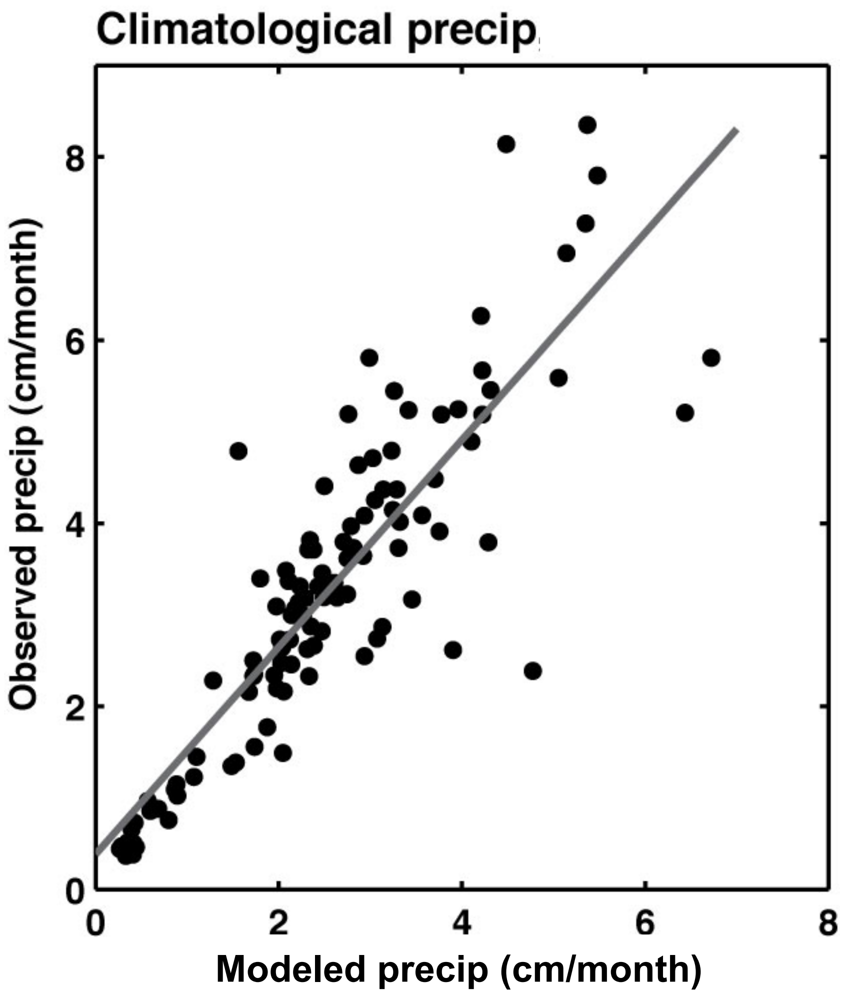
(1) Coarse-resolution archived climate data, going back in gridded format about 50 years. This allows for a high-resolution reconstruction of regional climate. We've demonstrated that this technique can reproduce climate variations with a high degree of skill.

(2) Global simulations of future climate change. This allows for simulations of regional effects of climate change. The regional model provides the details that coarse resolution global climate models cannot provide.



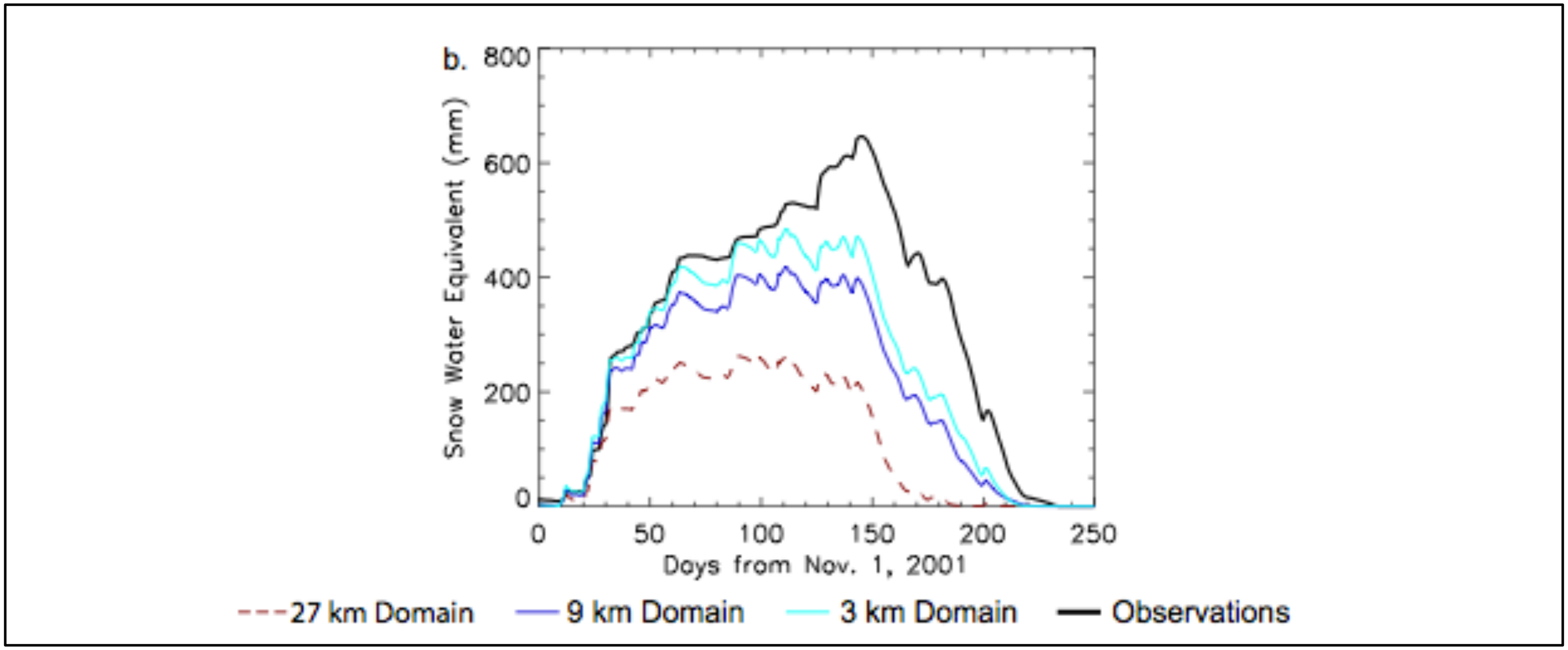
Accumulated precipitation in the WRF model during the 2001-2002 rainy season (November-May). Note the timing of individual storms and the realistic distribution of precipitation associated with mountains.

Validation of Climatological Precipitation
Observations vs. nearest model grid point



Correlation: 0.87
Regression slope: 1.13

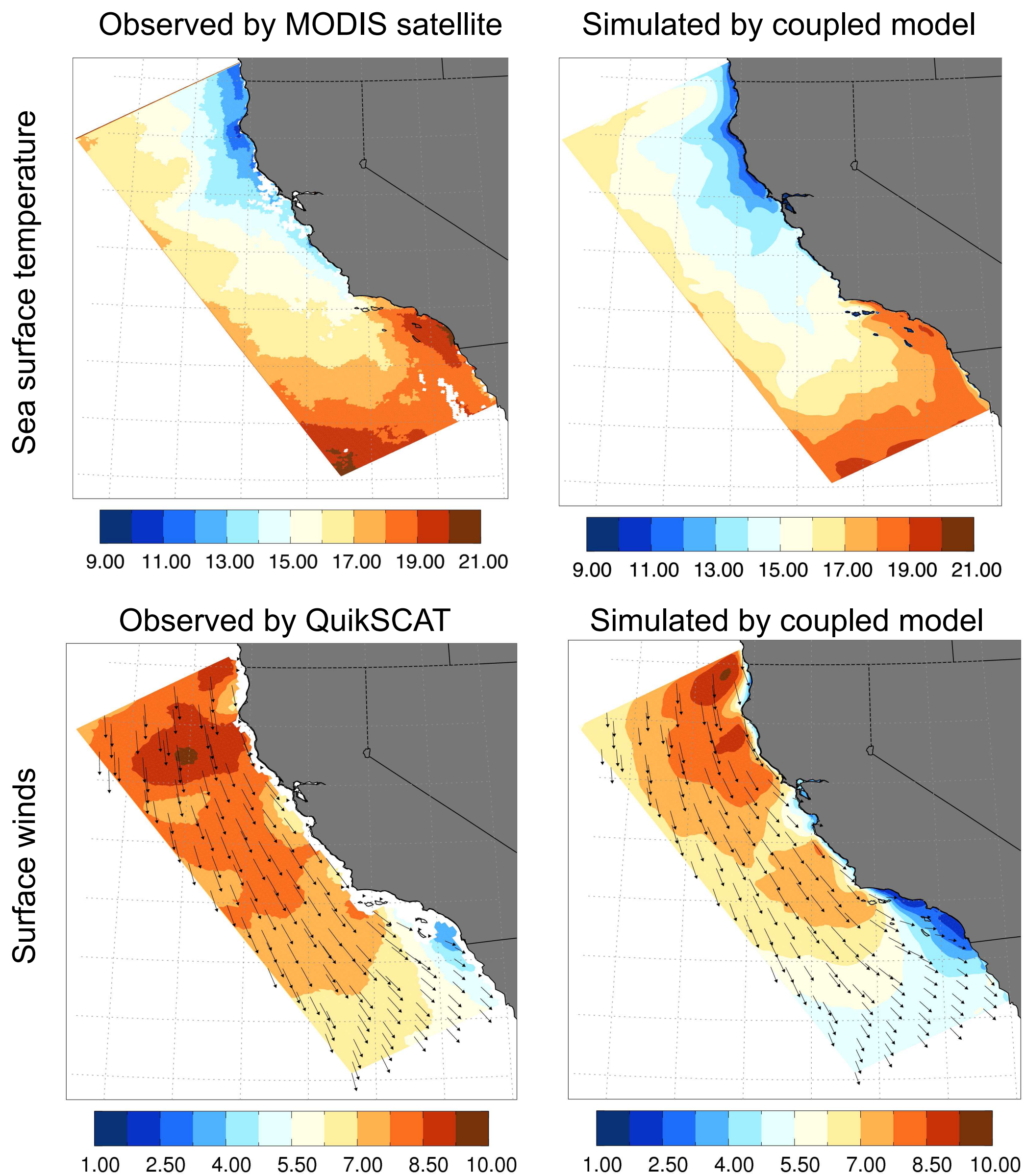
How well does WRF simulate snowpack in the Sierras?



This shows the snowpack evolution averaged over 41 observation stations in the Sierras and nearest model grid points for the 2001-2002 water year.

* Accuracy improves as grid cell resolution increases
* Snowpack accumulation is reasonably well simulated
* Errors associated with timing (~20 - 35 days early) of snowpack ablation are evident.

Validation of coastal processes in a regional coupled simulation (WRF/ROMS)



The alongshore flows produce an upwelling and cold SSTs in both model and observation.

Jun – Sep 2002

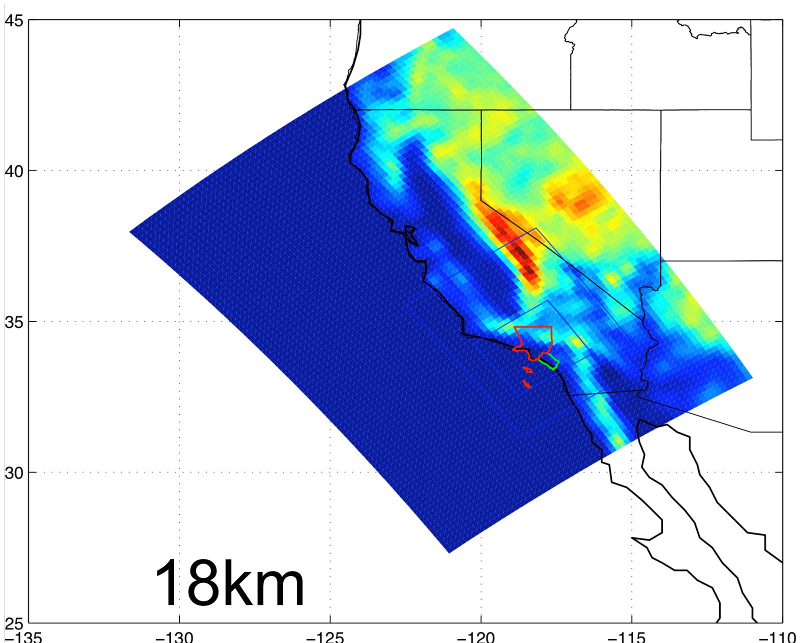
Boé et al. 2009

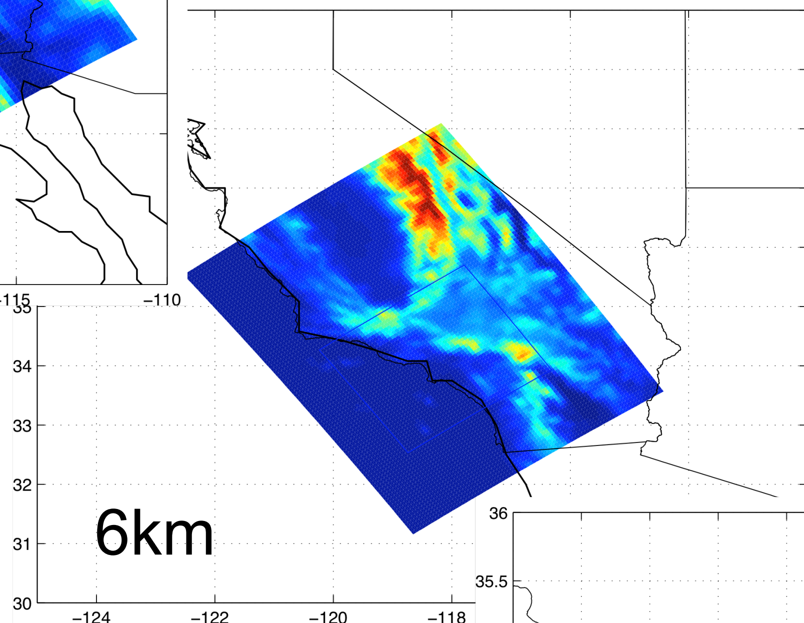
Climate Simulations to Inform a Los Angeles Regional Climate Action Plan

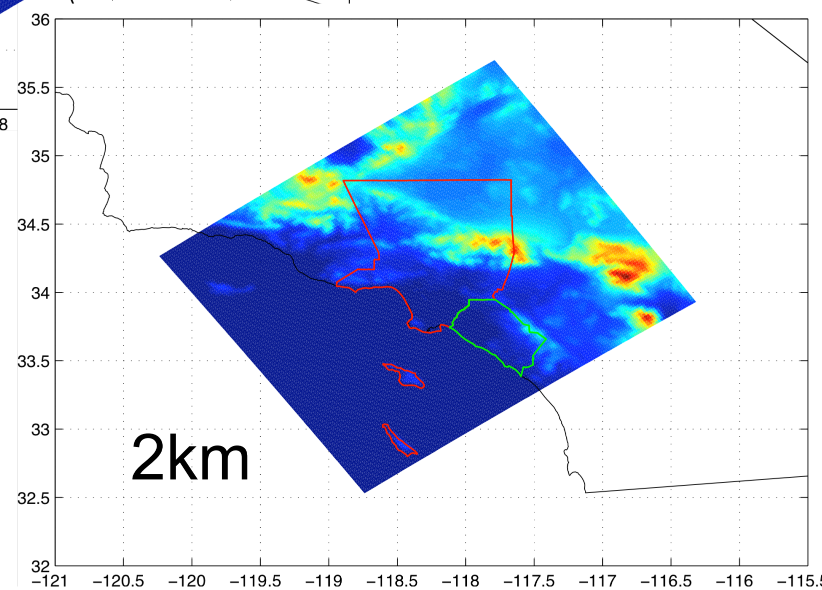
The project's goal is to provide quantitative information about climate change impacts on the Los Angeles region (heat waves, snowpack and water resources, fire, energy and water consumption, ecological impacts, etc.)

This information will be based not only projections of future climate but also estimates of the spread in projections at the regional scale.

Los Angeles Regional Simulation

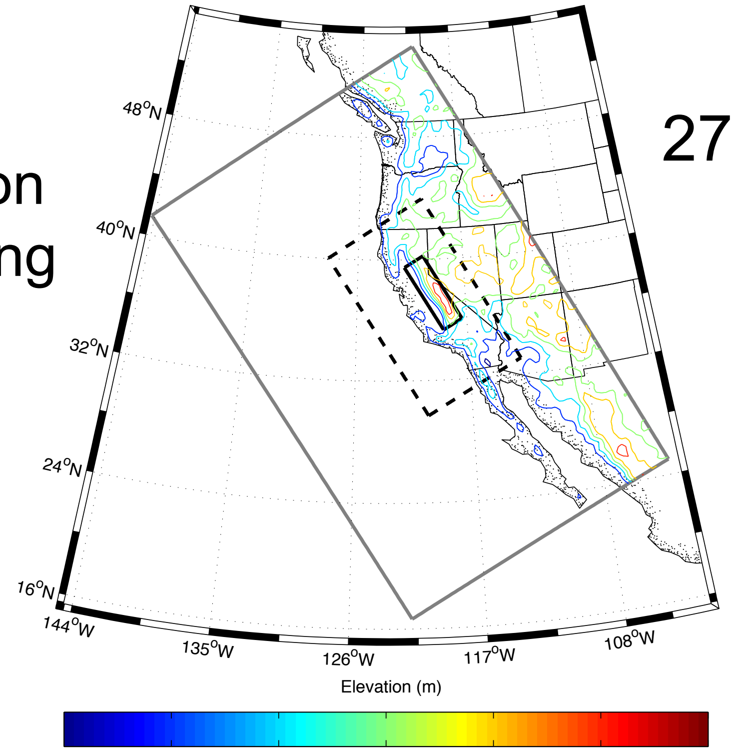






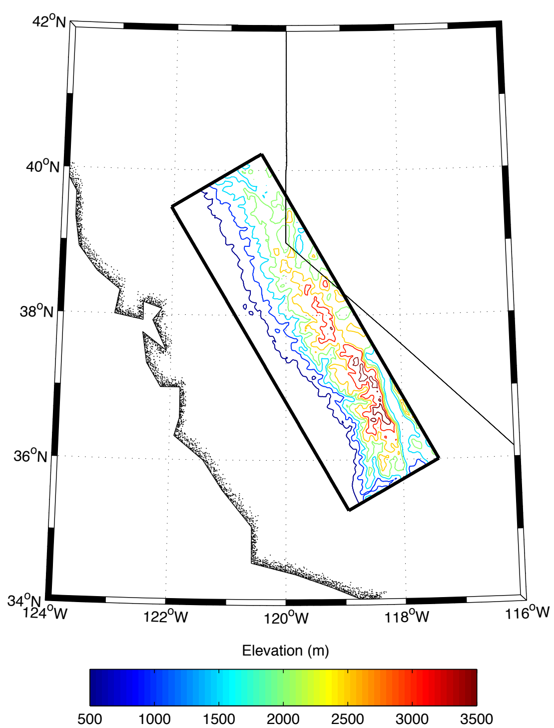
Dynamically downscaled simulation centered in the Los Angeles region using WRF + Noah land surface model

Dynamically downscaled simulation over Western US using WRF + Noah land surface model

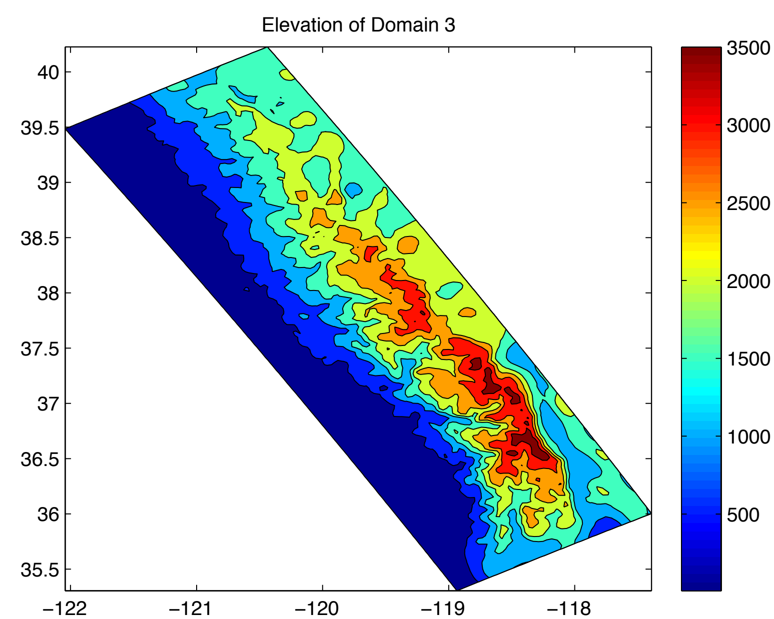


27 km → 9 km → 3 km

Sierras Regional Simulation

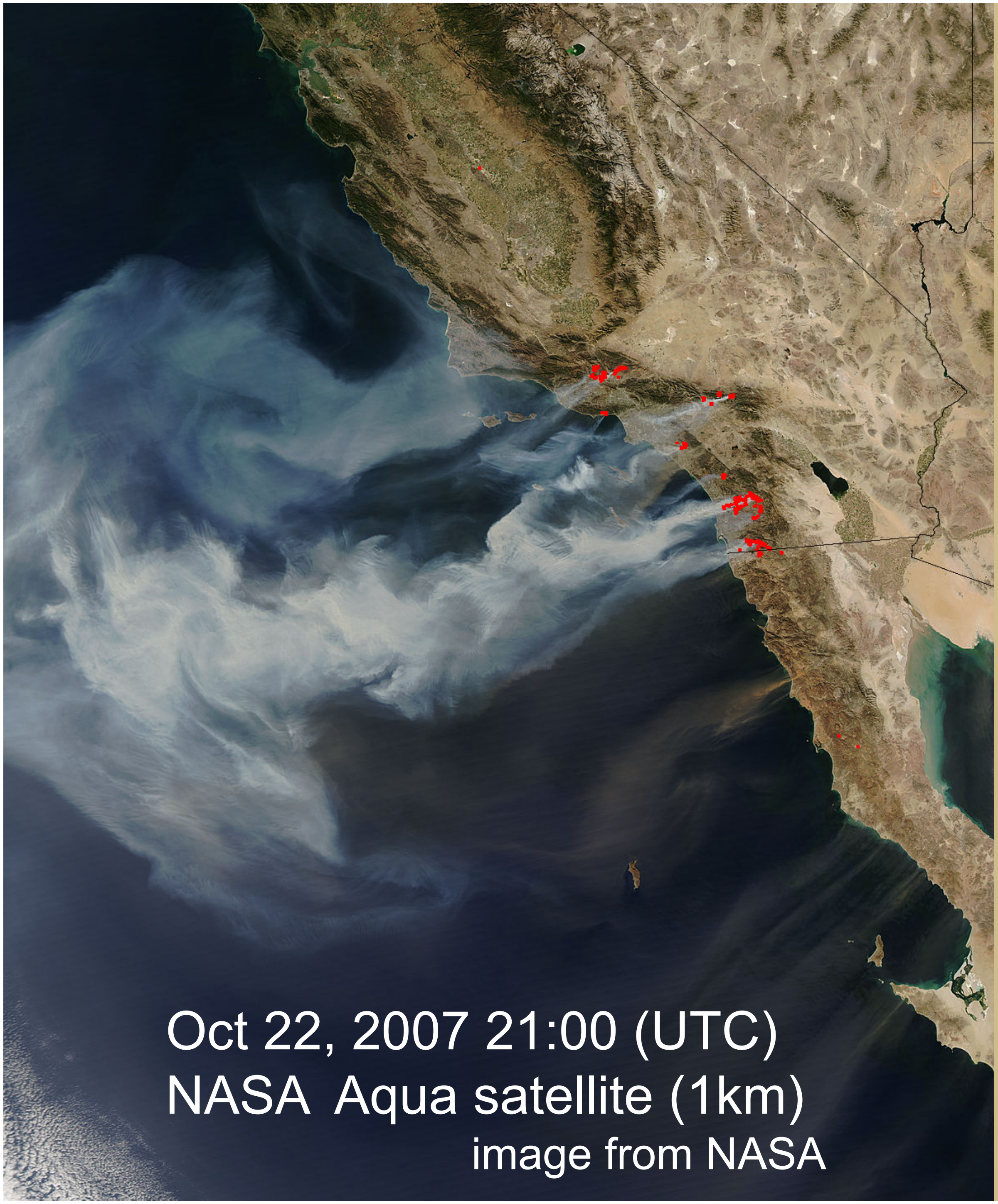


Innermost 3 km resolution domain focuses on the Sierra Nevada Mountains in Central California



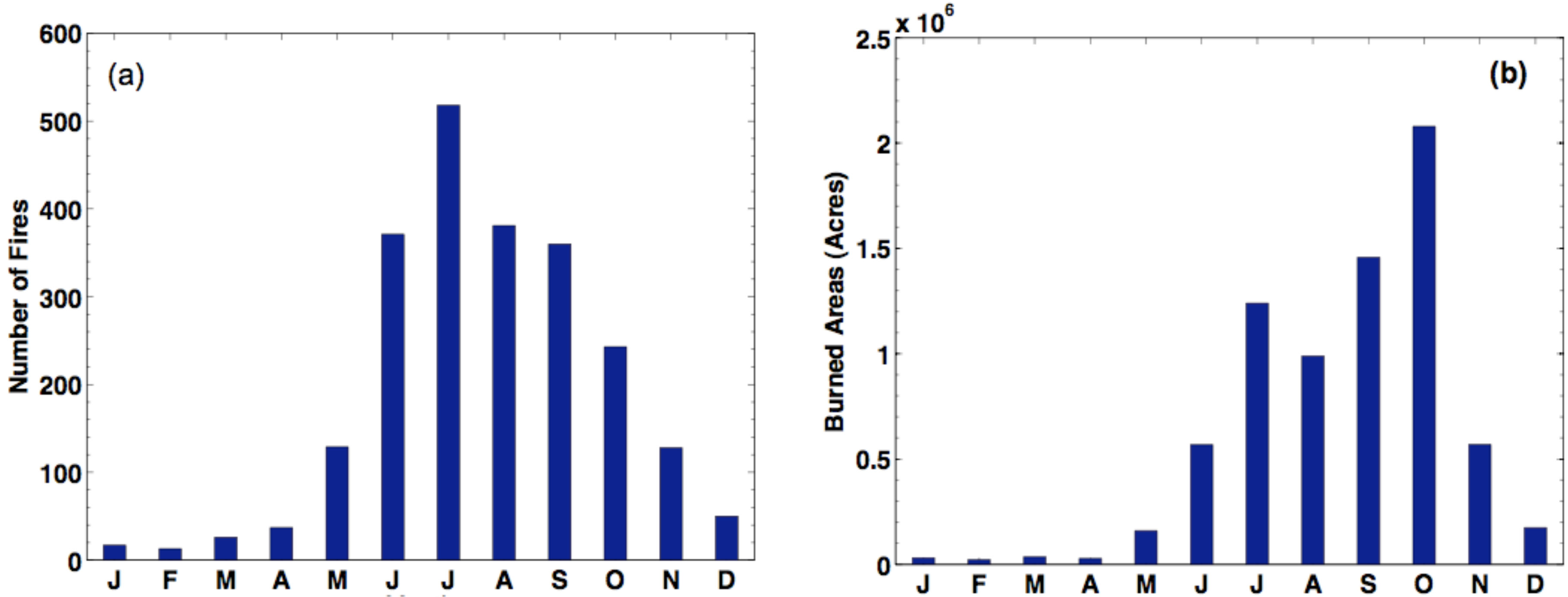
Simulations for Los Angeles Regional Climate Action Plan

Region	Current-day run	Climate change run (A2 scenario)	Statistical downscaling
Los Angeles Region	1991-2010 (Reanalysis and NCAR CCSM)	2041-2060 (NCAR CCSM)	AR4/AR5 GCMs
The Sierras	1991-2010 (Reanalysis and NCAR CCSM)	2041-2060 (NCAR CCSM)	AR4/AR5 GCMs



Example: Climate Change Impacts on Fire in Southern California

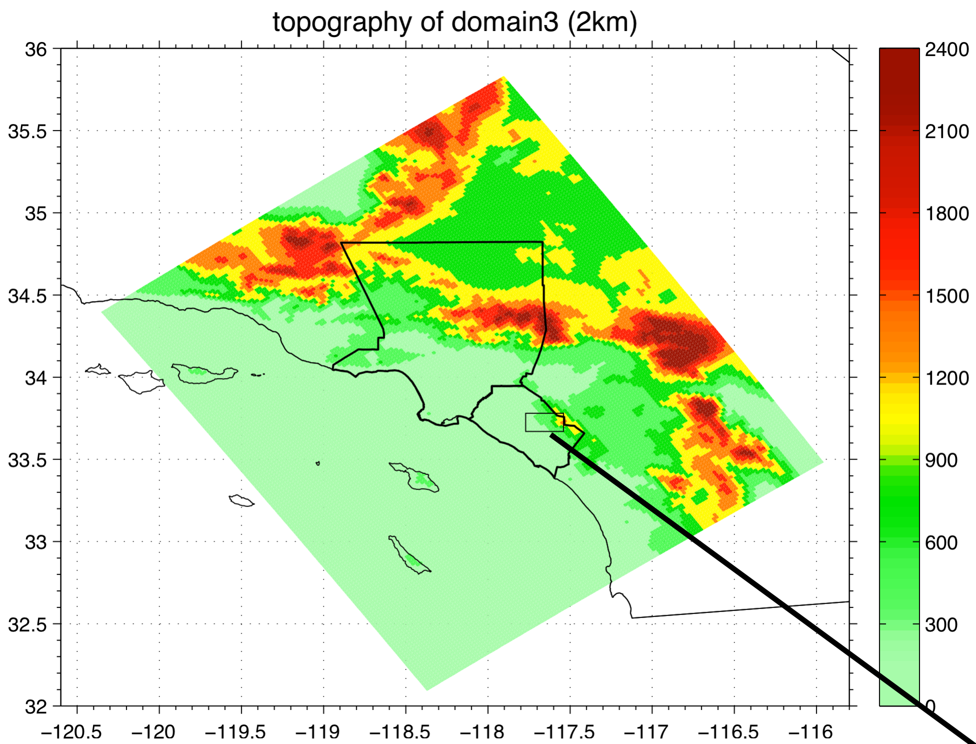
Climatological fire number and size in Southern California



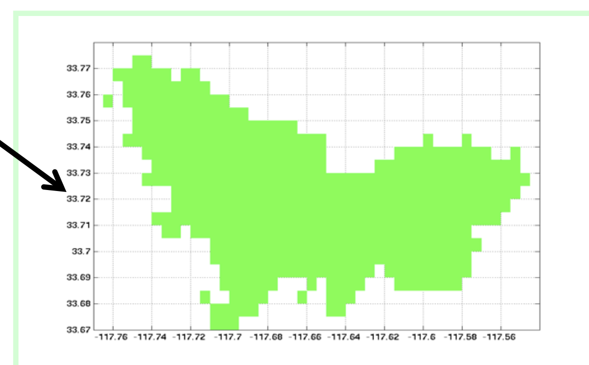
• Historical fire data (1950-2009) comes from California's Fire and Resource Assessment Program (FRAP)

• While the number of fires is clearly associated with the seasonal cycle of temperature, the fires only become large once the Santa Anas begin in September and October.

Jin et al. 2011



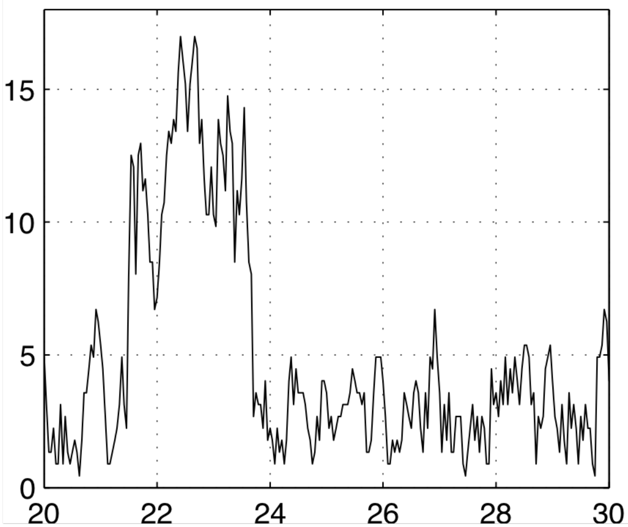
We examined the simulated and observed meteorology during one of the fires, the October 2007 Santiago fire.



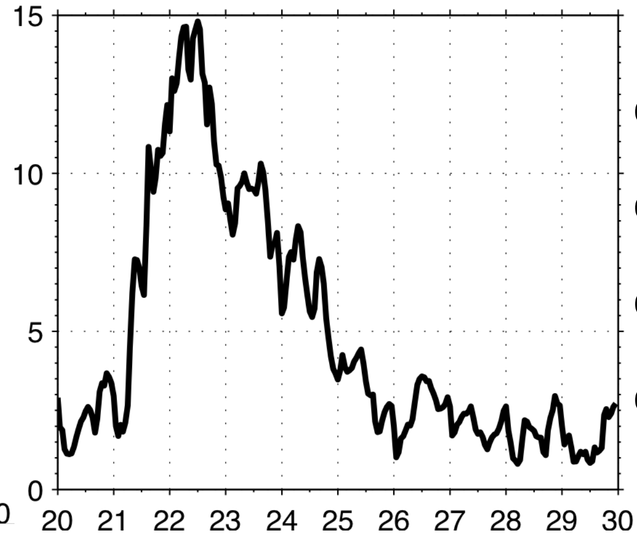
extent of the Santiago fire (MODIS data retrieved)

Observed and simulated meteorological conditions over during the Santiago fire in October 2007

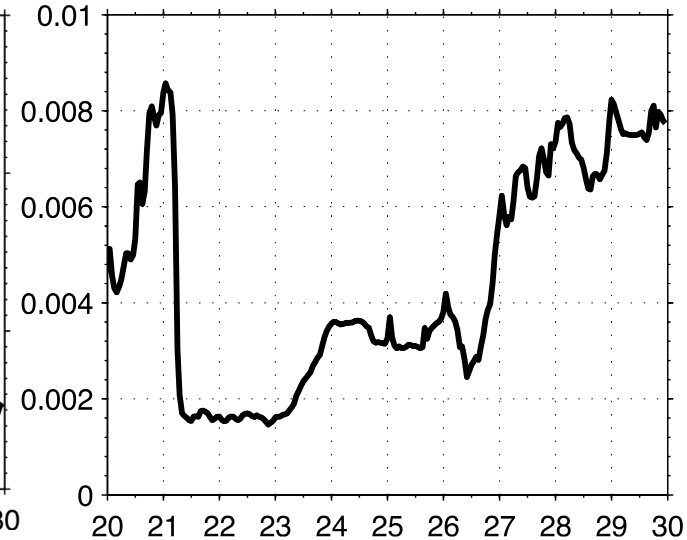
Observed wind speed



WRF wind speed



WRF humidity

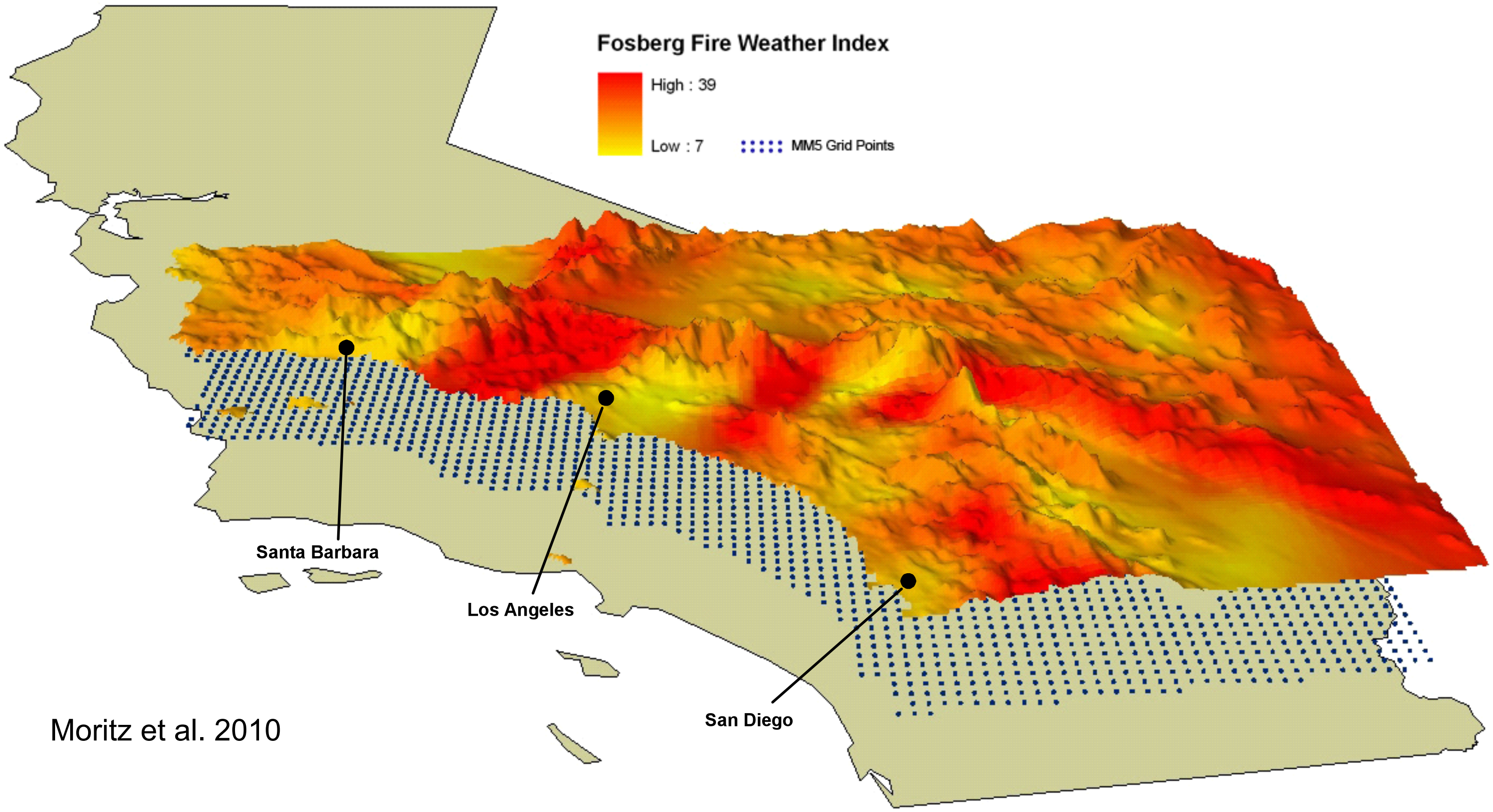


Observed surface wind speed at Fremont canyon (data source: California Data Exchange Center)

WRF simulated surface wind speed and specific humidity averaged over box encompassing Santiago fire

(x-axes show day in October 2007)

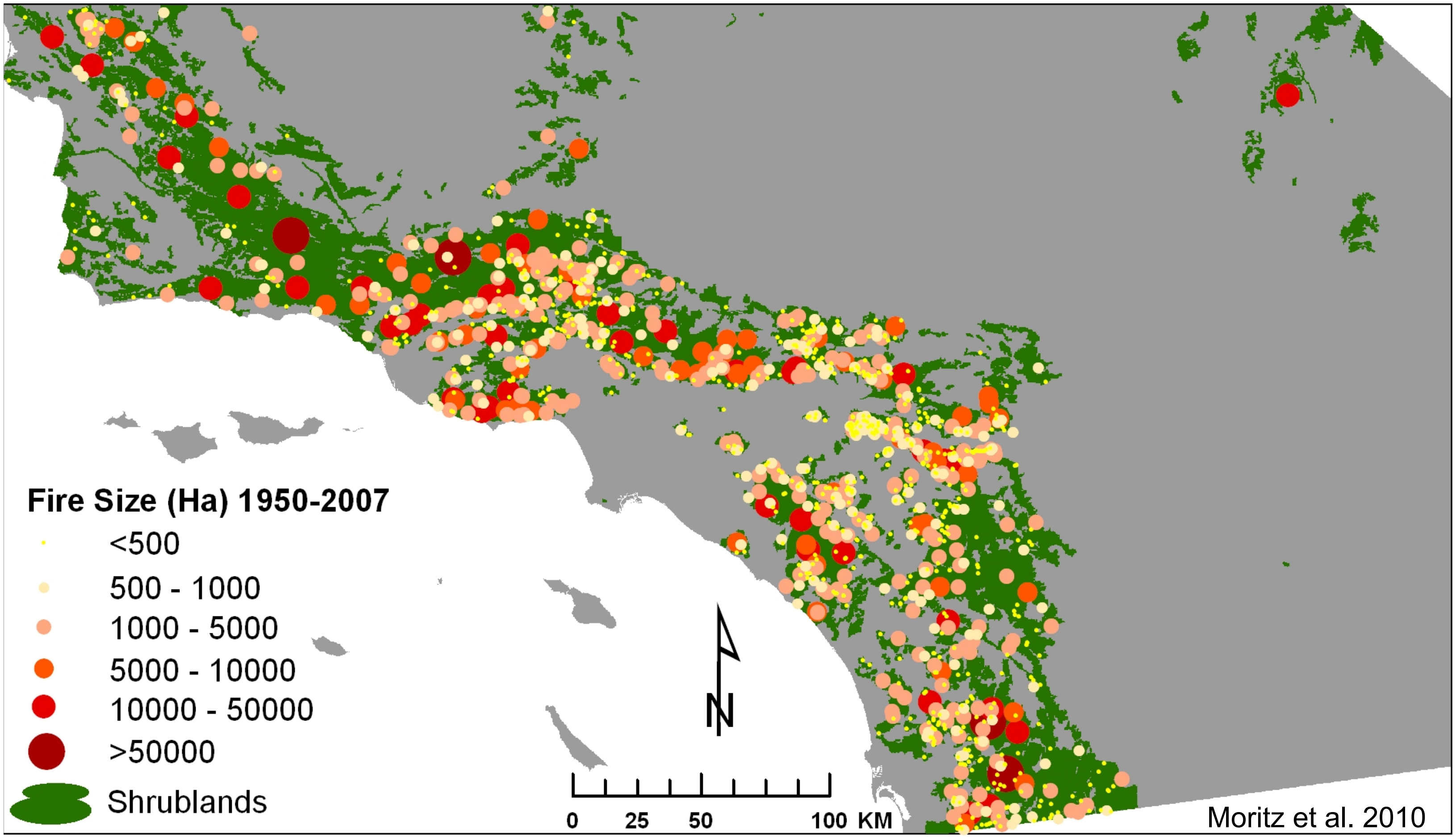
The Santa Anas and Fire



Moritz et al. 2010

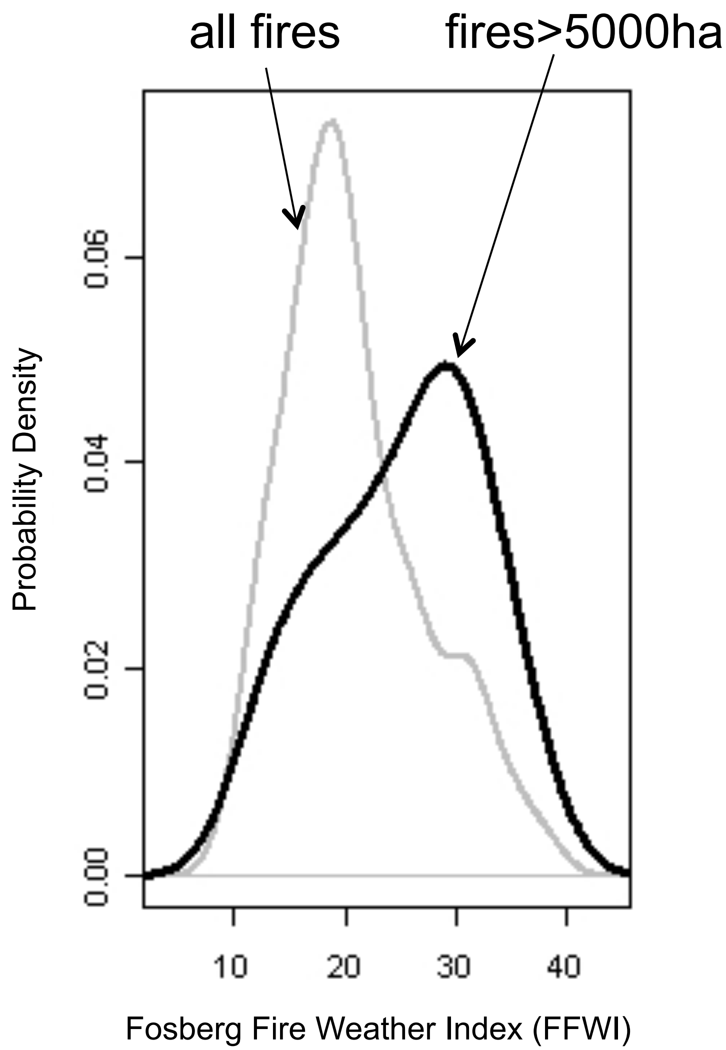
We imposed the average simulated meteorological conditions during Santa Ana events on a model of fire behavior. The fire behavior model quantifies fire risk for given environmental conditions. Enhanced fire risk is clearly seen in passes where Santa Ana flows are channeled.

Fire History in Southern California



This map shows the centers of past fires and their size. What is the relationship between fire size and fire risk as quantified by the atmospheric simulation and the fire behavior model?

Relation between Fire Weather and Fire Size



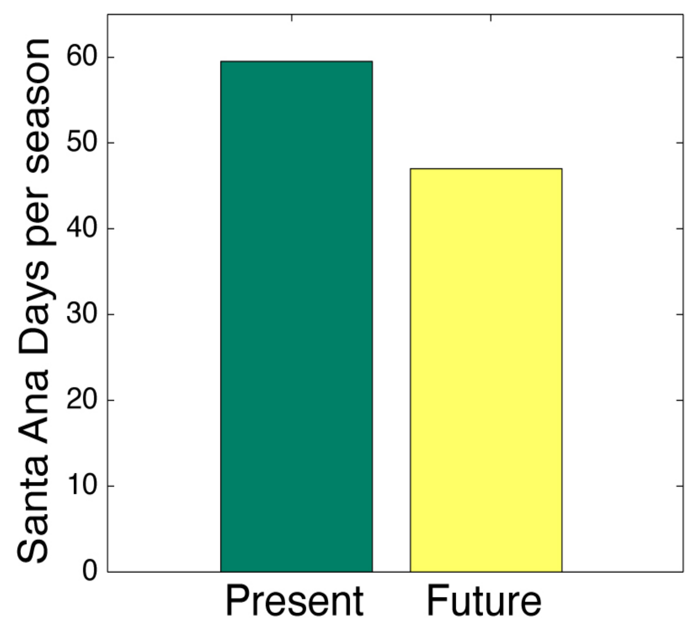
Moritz et al. 2010

The probability density function of fire as a function of simulated fire risk shows a clear relationship between fire size and fire risk. Though fires appear equally likely to be ignited no matter where they are located, they are much more likely to become large fires if they are located in an area of large fire risk.

The Santa Anas in a future climate simulation

We have already performed a 12 km climate change simulation with WRF, forced by a CCSM scenario run

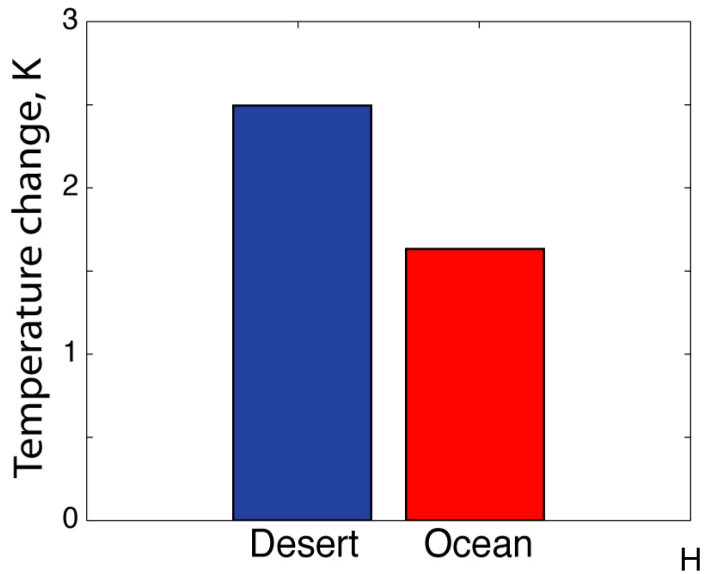
When we impose the conditions of a global future climate simulation of the regional model boundaries, we see a reduction in the number of Santa Ana days.



(1971-1980) (2045-2055)

Hughes et al. 2010

Differential Warming of Land and Ocean

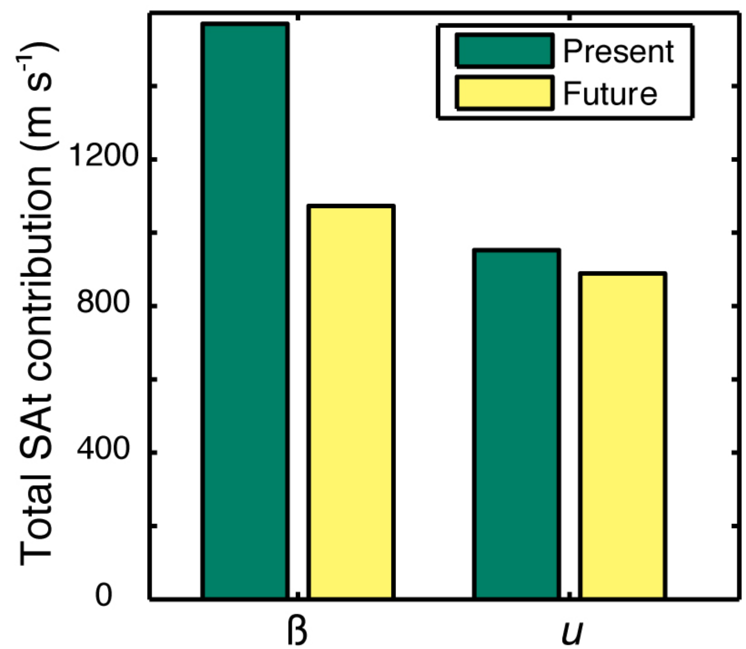


Hughes et al. 2010

A well-known aspect of transient climate change is the more rapid warming over dry land areas than the ocean. This phenomenon is clearly seen in the regional simulation This may weaken the local mechanism generating Santa Anas.

Mechanisms generating Santa Anas

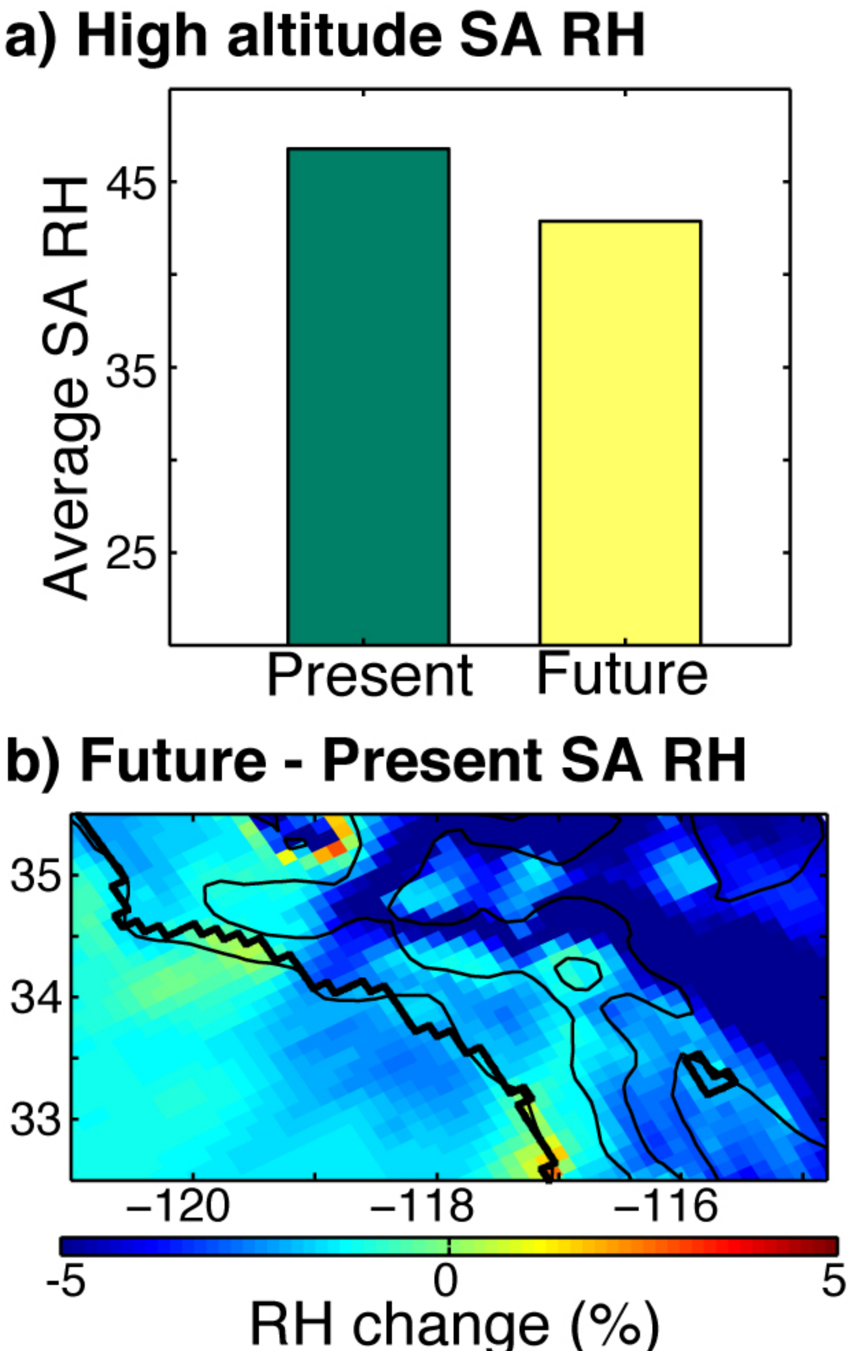
It turns out there are two mechanisms generating Santa Anas. One contributes significantly less to Santa Ana strength in the future climate. This is the local, thermodynamic mechanism. It operates when the desert air becomes significantly colder and denser than the nearby coastal air, driving flow down from the desert plateau to the coastal zone through the mountain passes.



local mechanism, thermodynamic

continental-scale mechanism, dynamic

Hughes et al. 2010



Hughes et al. 2010

Consequences for fire

The decrease in frequency of Santa Ana events has ambiguous consequences for fire because it is also accompanied by a decrease in relative humidity. These drying and warming effects must be balanced against the reduction in winds using a fire behavior model.

Moreover, fire occurrence is likely sensitive to other climate variables as well.

Future Directions

- Relate characteristics of individual Santa Ana events, including intensity and duration, to individual fire events to determine sensitivity of fire to Santa Anas more precisely.
- Understand the sensitivity of fire size to fuels development in the previous wet season
- Establish the hydrologic conditions that "turn off" the power of Santa Ana events to increase fire risk
- Examine climate-change-induced changes in key variables to make projections of changes in fire due to climate change.